

A Low Frequency Radio and Radar Instrument to Explore Jupiter's Icy Moons

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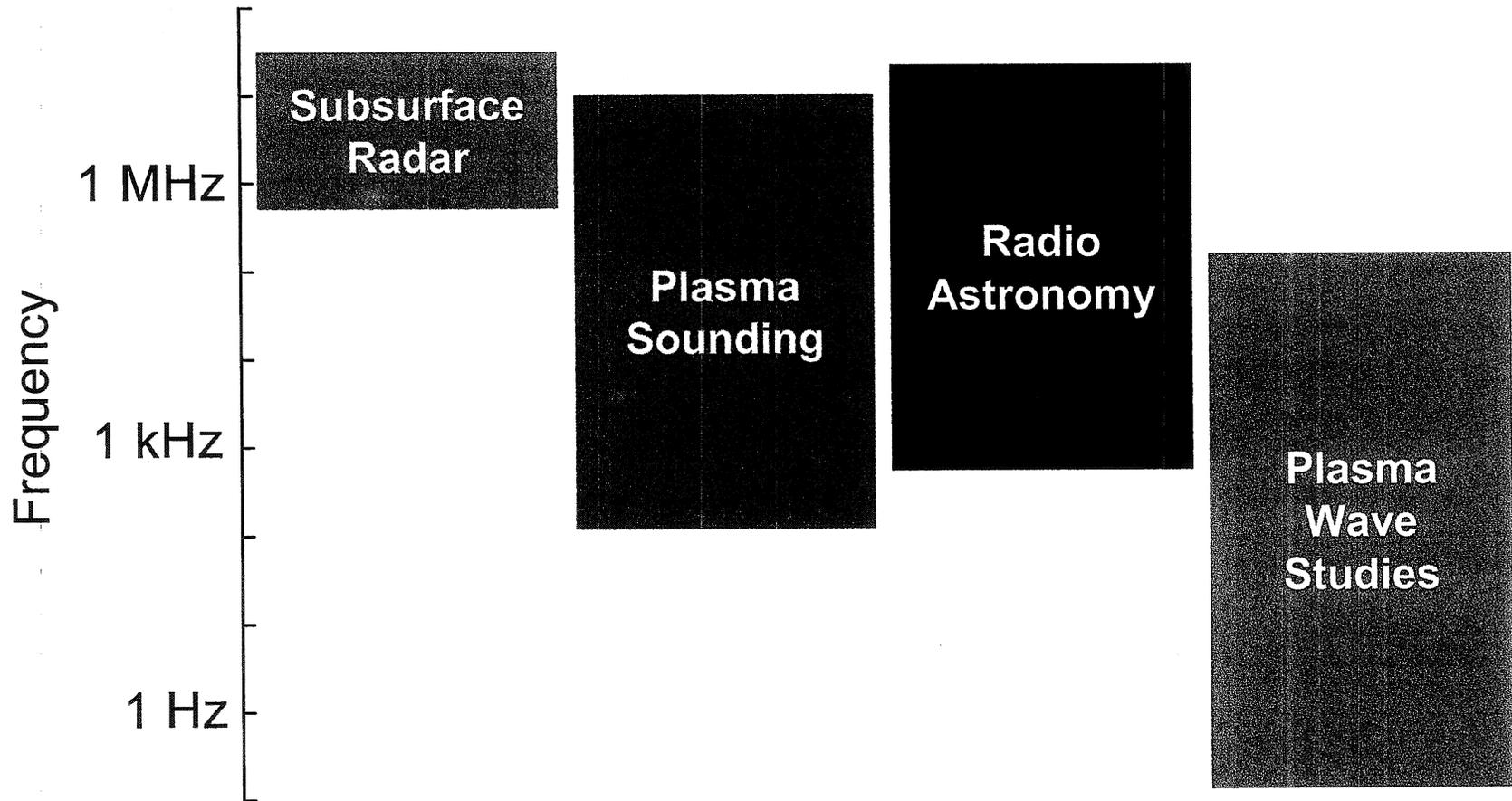
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⁵U. Of California, Berkeley

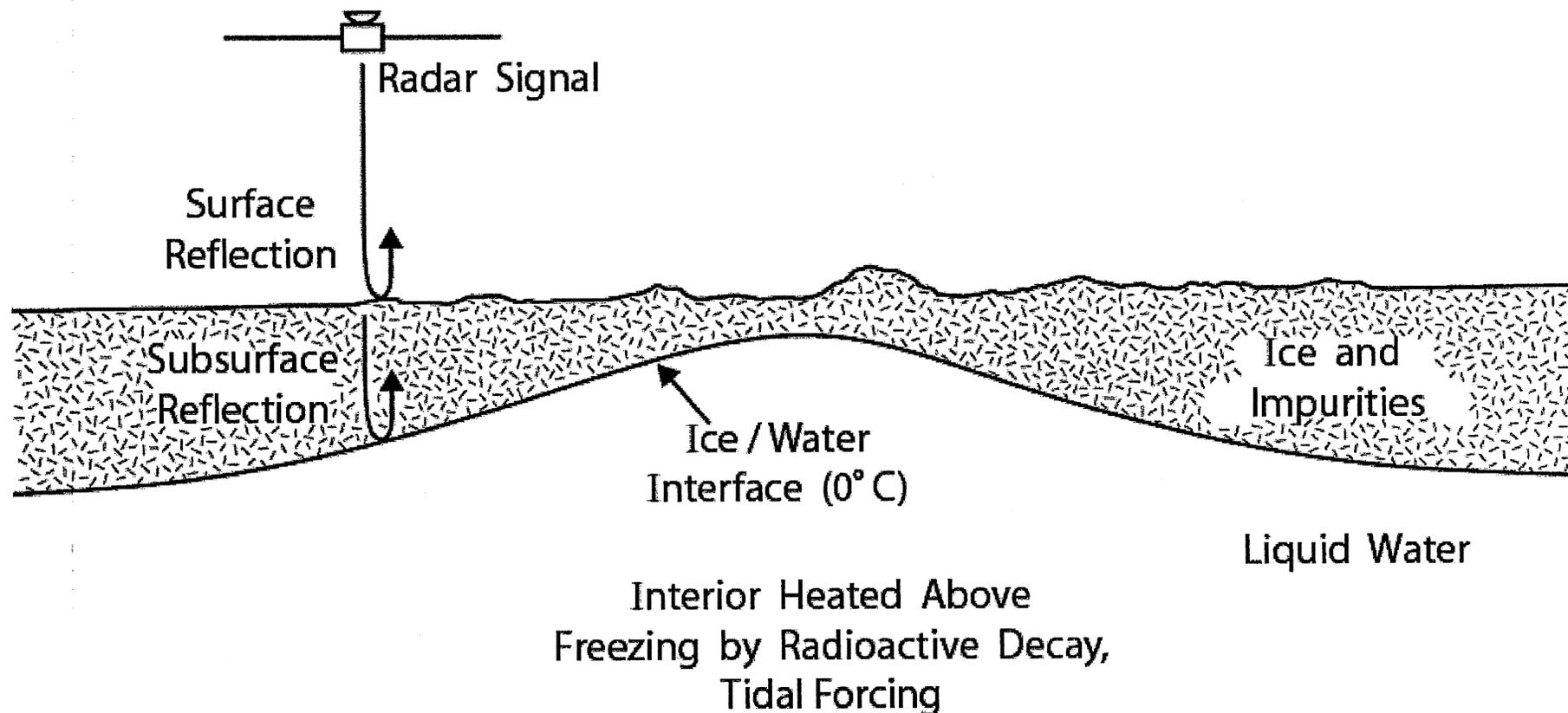
Using Waves to Explore Jupiter's Icy Moons and Magnetosphere



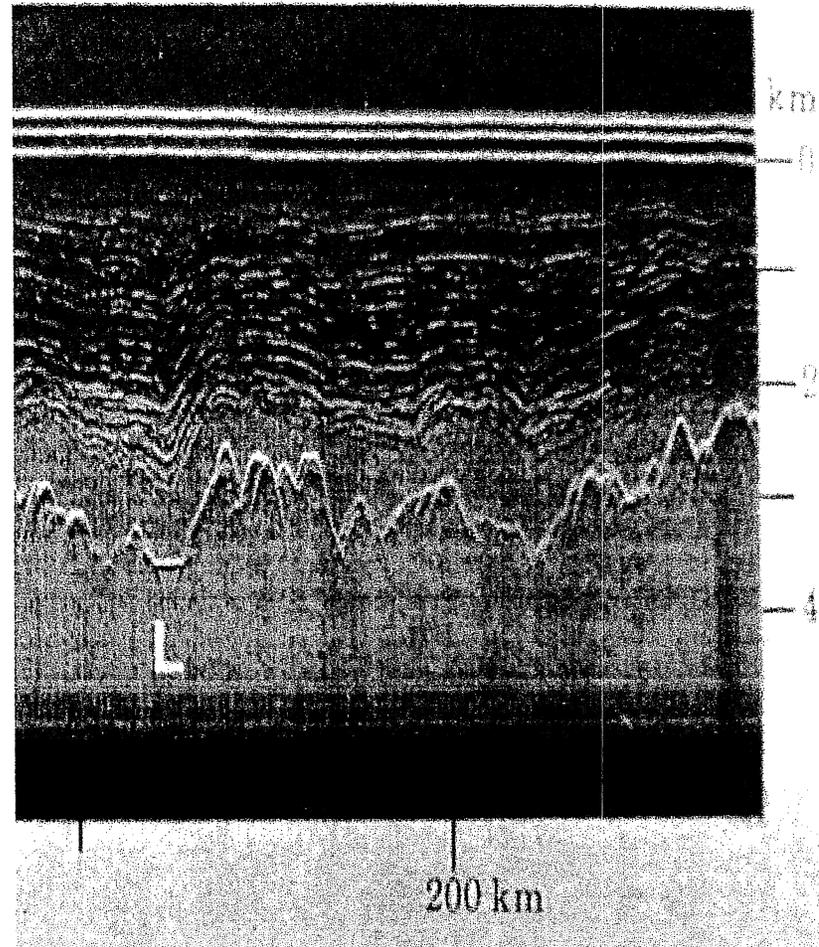
Science Objectives

- Determine the potential for life
 - Confirm the existence of and characterize sub-surface oceans in the icy satellites
 - Determine the thickness of the ice crust

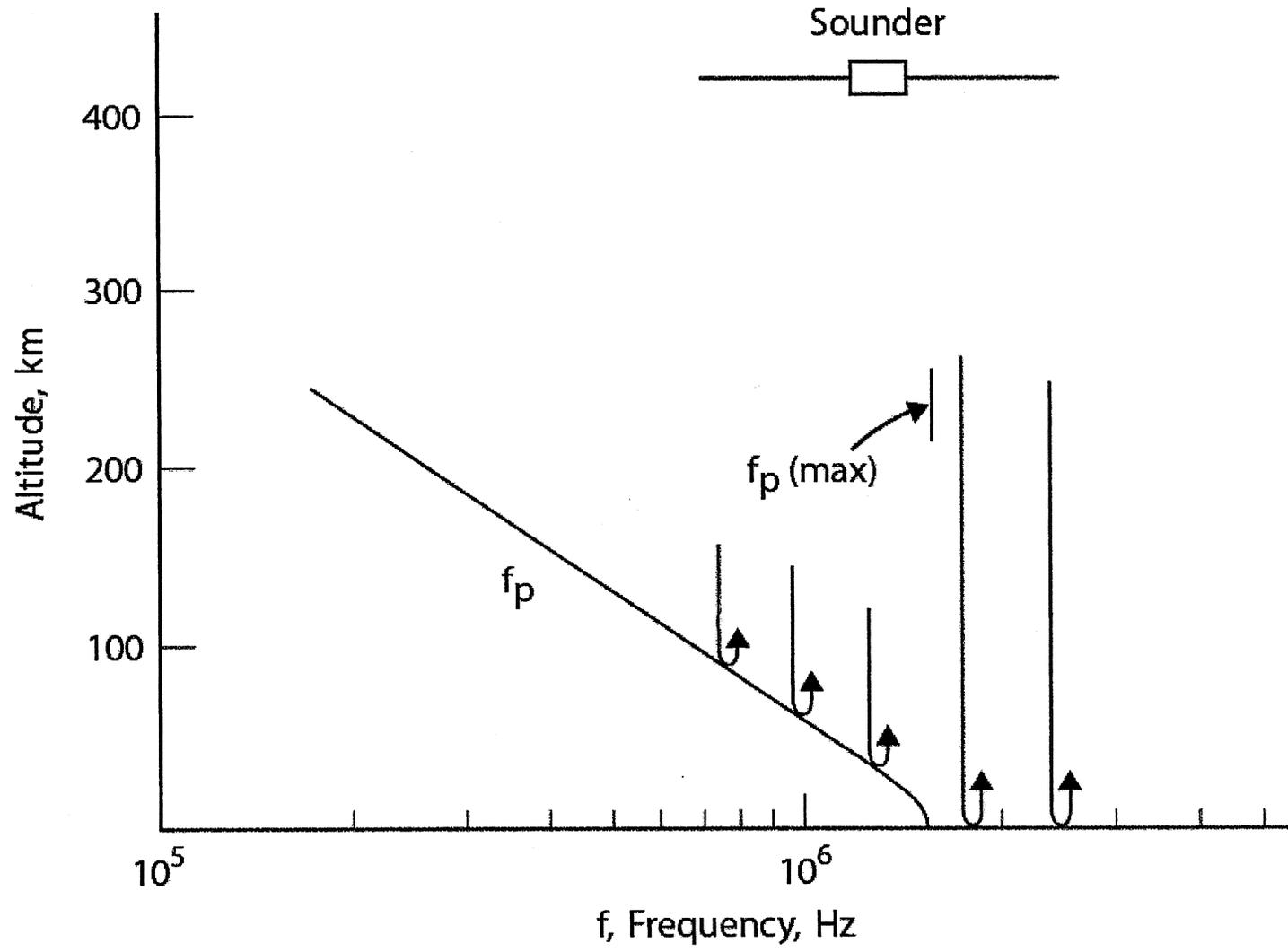
JIMO Low Frequency Subsurface Radar Sounder



60-MHz Radar Observations of an Antarctic Lake Under Ice



Robin et al., *Philos. Trans. R. Soc. London Ser. B.* 1977.



Maximum Ionospheric Densities and Plasma Frequencies

• Callisto ¹	17,400 cm ⁻³	1.2 MHz
• Ganymede ²	400 cm ⁻³	180 kHz
• Europa ³	9,000 cm ⁻³	900 kHz
• Io ⁴	277,000 cm ⁻³	4.7 MHz

¹Kliore et al., *JGR*, 2002.

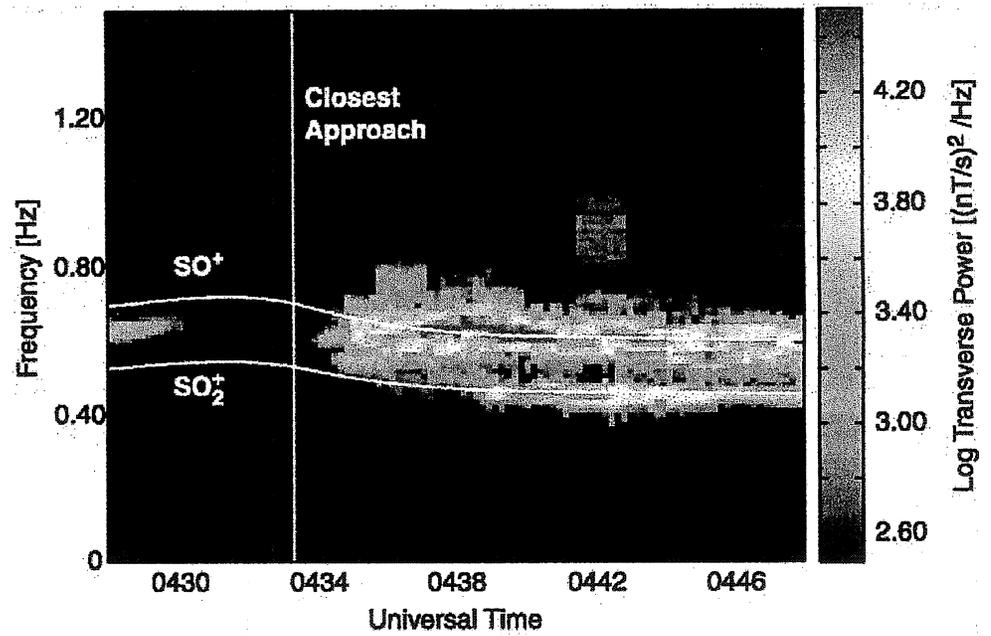
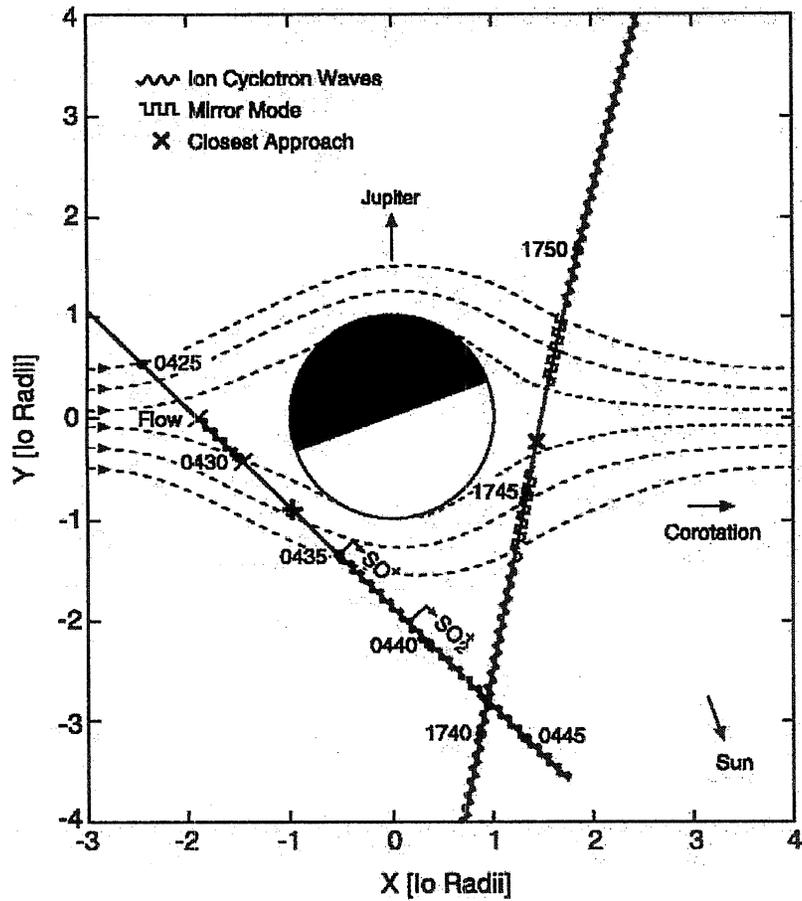
²Eviatar et al., *PSS*, 2001.

³Kliore et al., *Science*, 1997.

⁴Hinson et al., *JGR*, 1998.

Science Objectives, cont.

- Origins and Evolution
 - Characterize the nature of the icy crust including scattering properties, existence of impurities, brine inclusions, and temperature profile
 - Determine the surface composition and characterize the sputtering process through ultra-low frequency spectroscopy of ion cyclotron waves (in conjunction with magnetic field investigation).



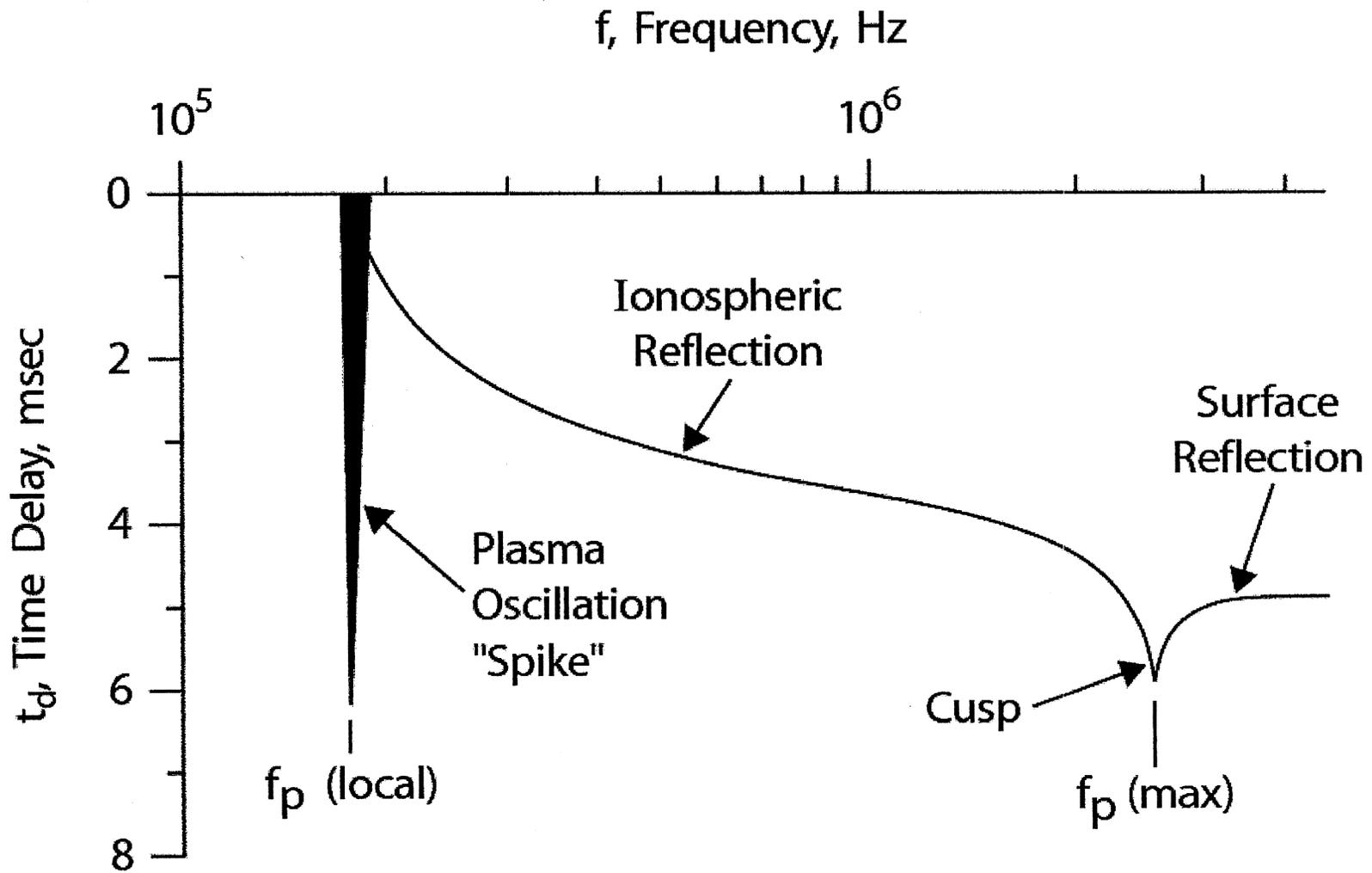
Russell & Kivelson, *Science*, 1998.

Science Objectives, cont.

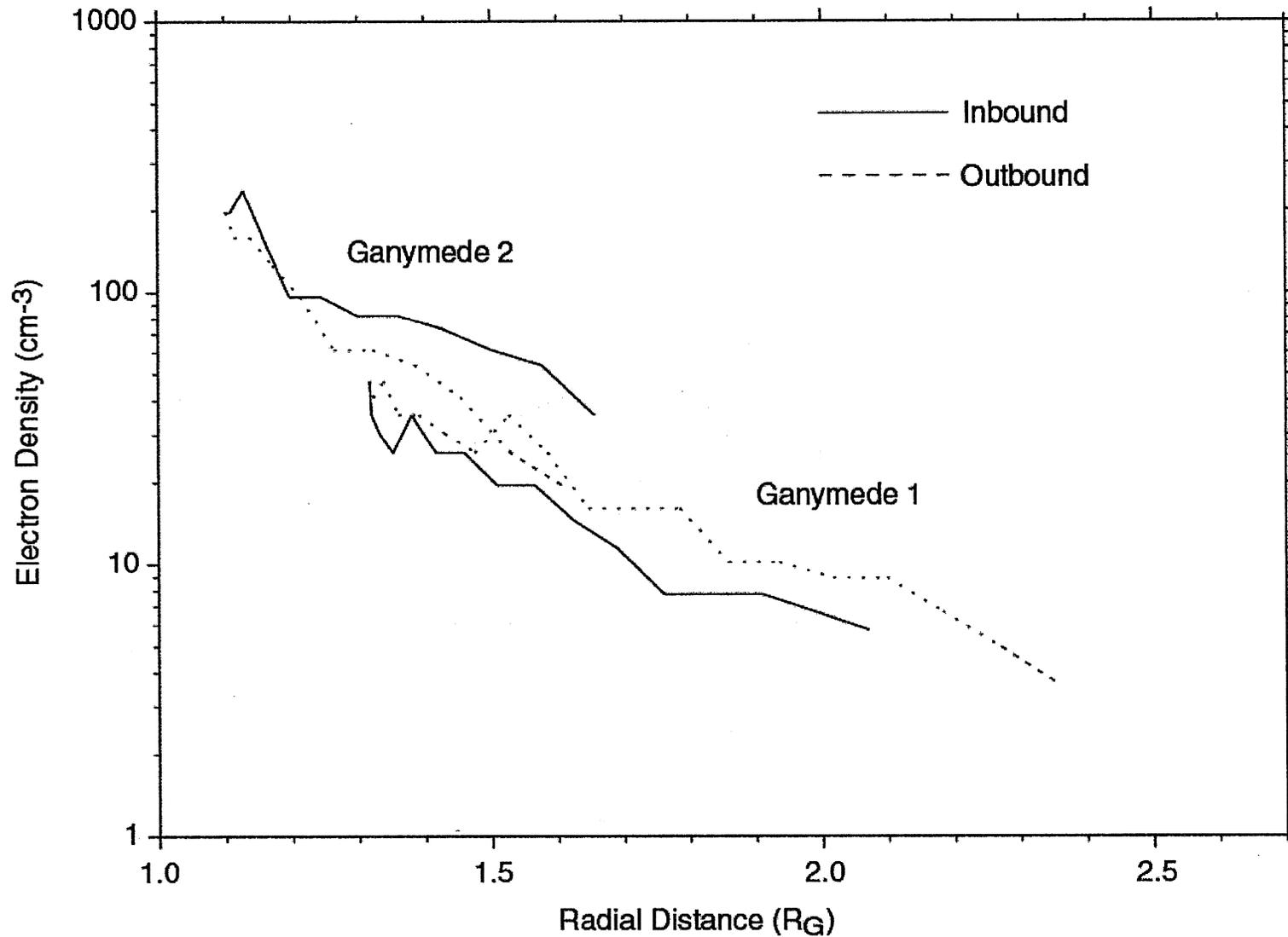
- Radiation Environment
 - Determine the structure and dynamics of the ionospheres associated with the icy satellite exospheres
 - Characterize the magnetospheric interaction with the icy satellites
 - Provide magnetospheric boundary conditions of the background magnetosphere, especially the plasma density.
 - Determine the structure and dynamics of the magnetosphere via in situ observations of plasma waves
 - Monitor magnetospheric dynamics via remote observations of Jovian radio emissions
 - Extend our knowledge of the source location and polarization of Jovian radio emissions.

Plasma Density Measurement Techniques

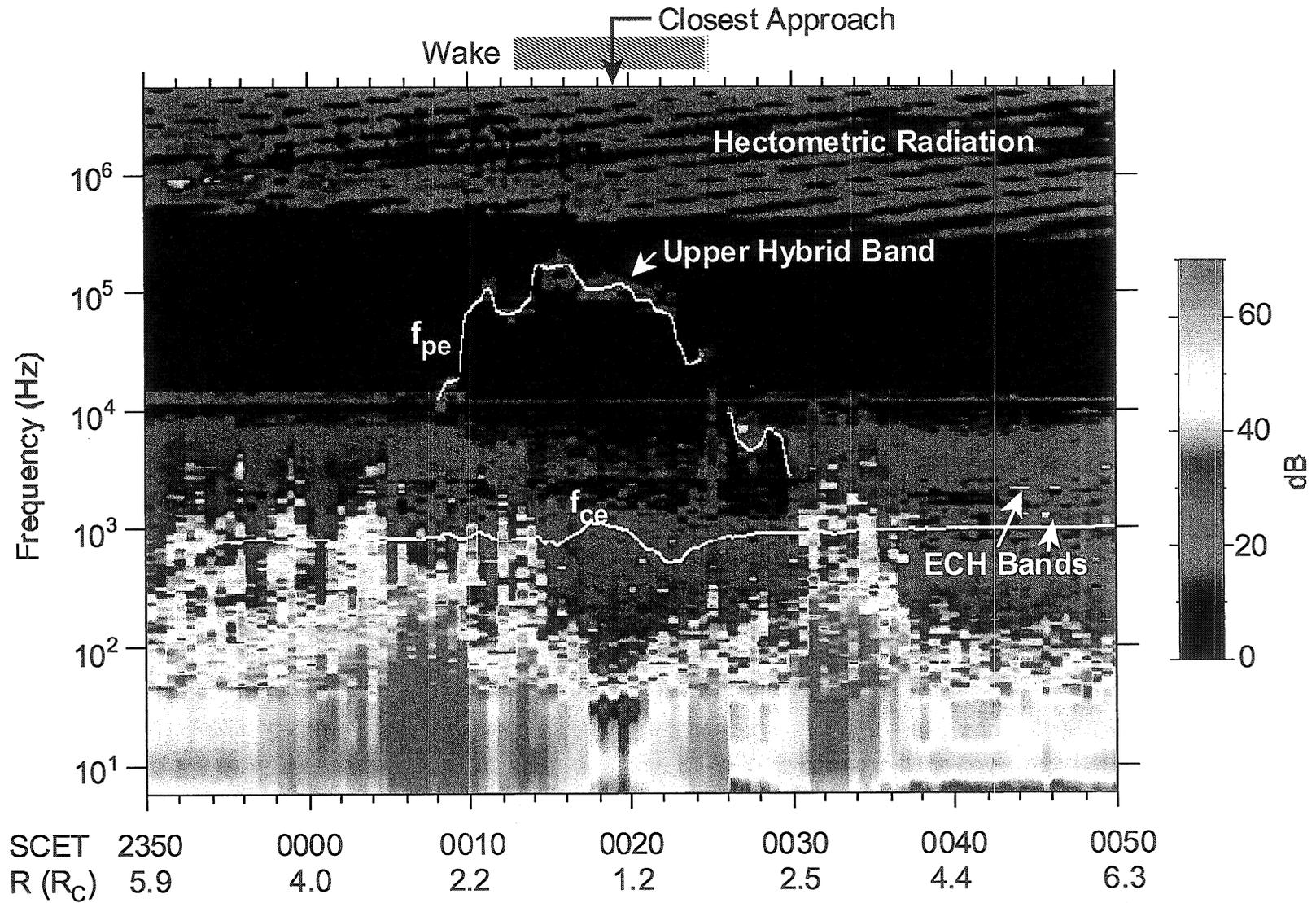
- Sounding
- Natural wave resonances or cutoffs
- Langmuir Probe
- Quasi-thermal plasma noise (long antennas, quiet spacecraft)



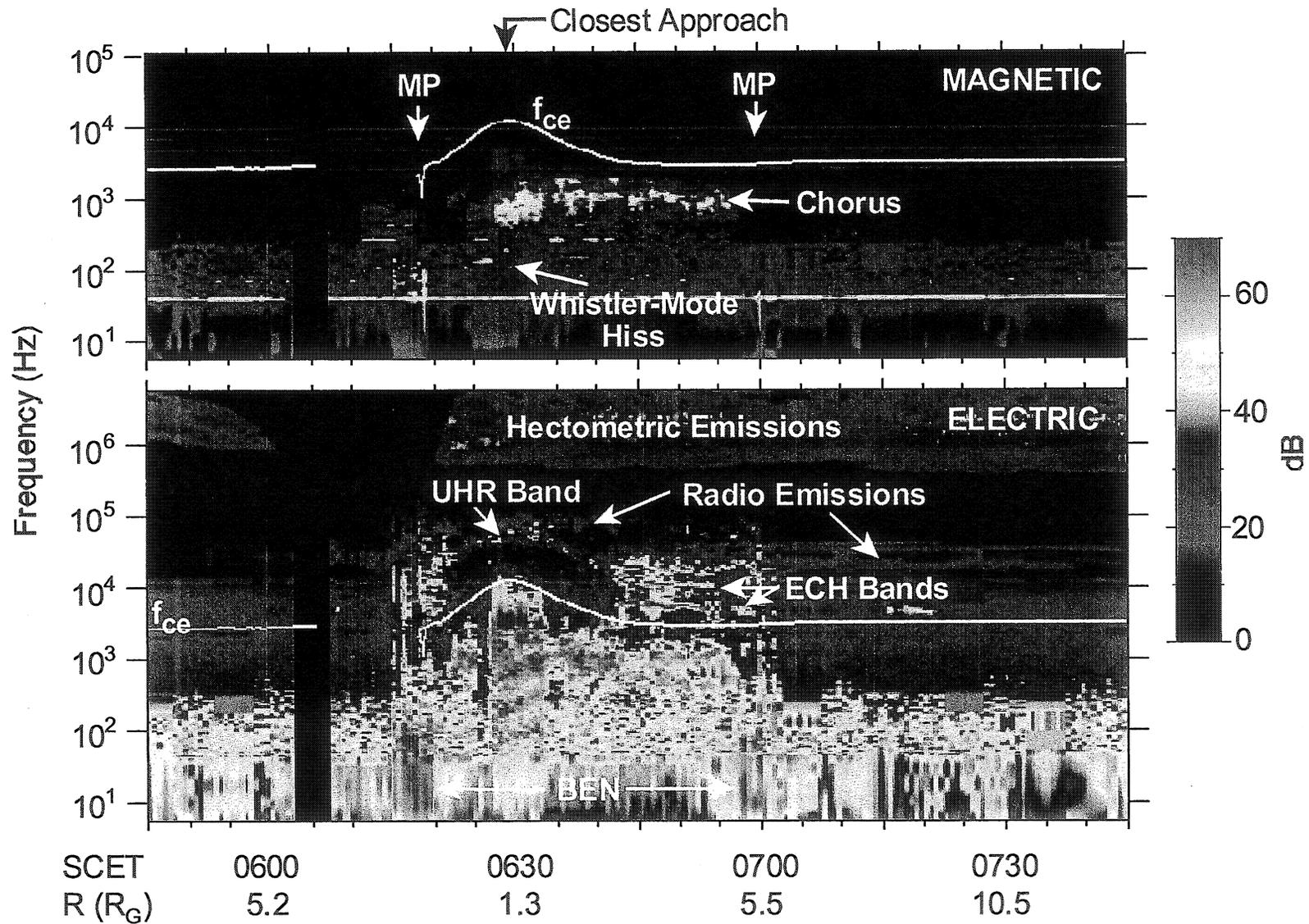
Ganymede's Ionospheric Profile



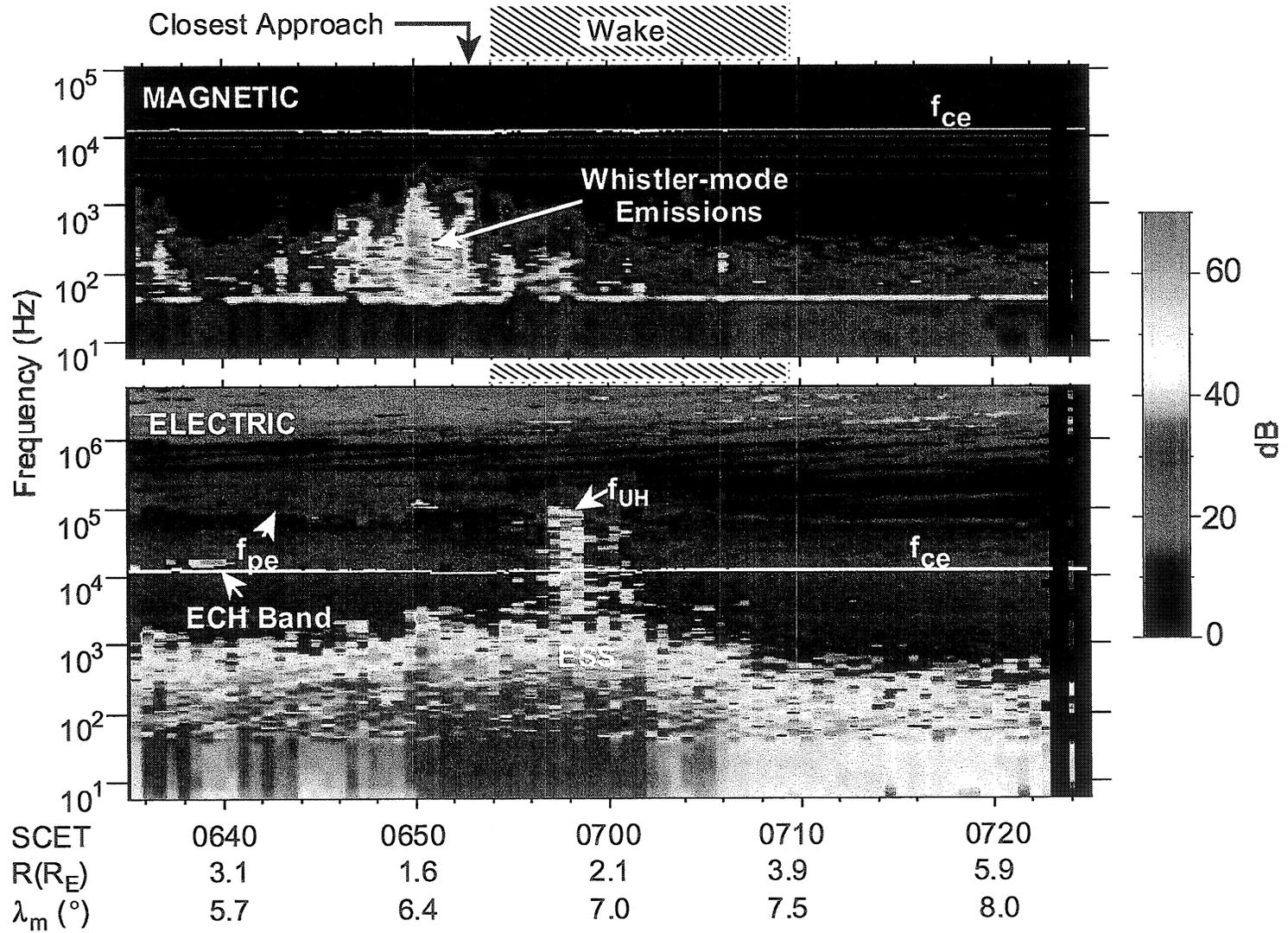
Galileo -- Callisto 10
16 - 17 September, Days 259-260, 1997

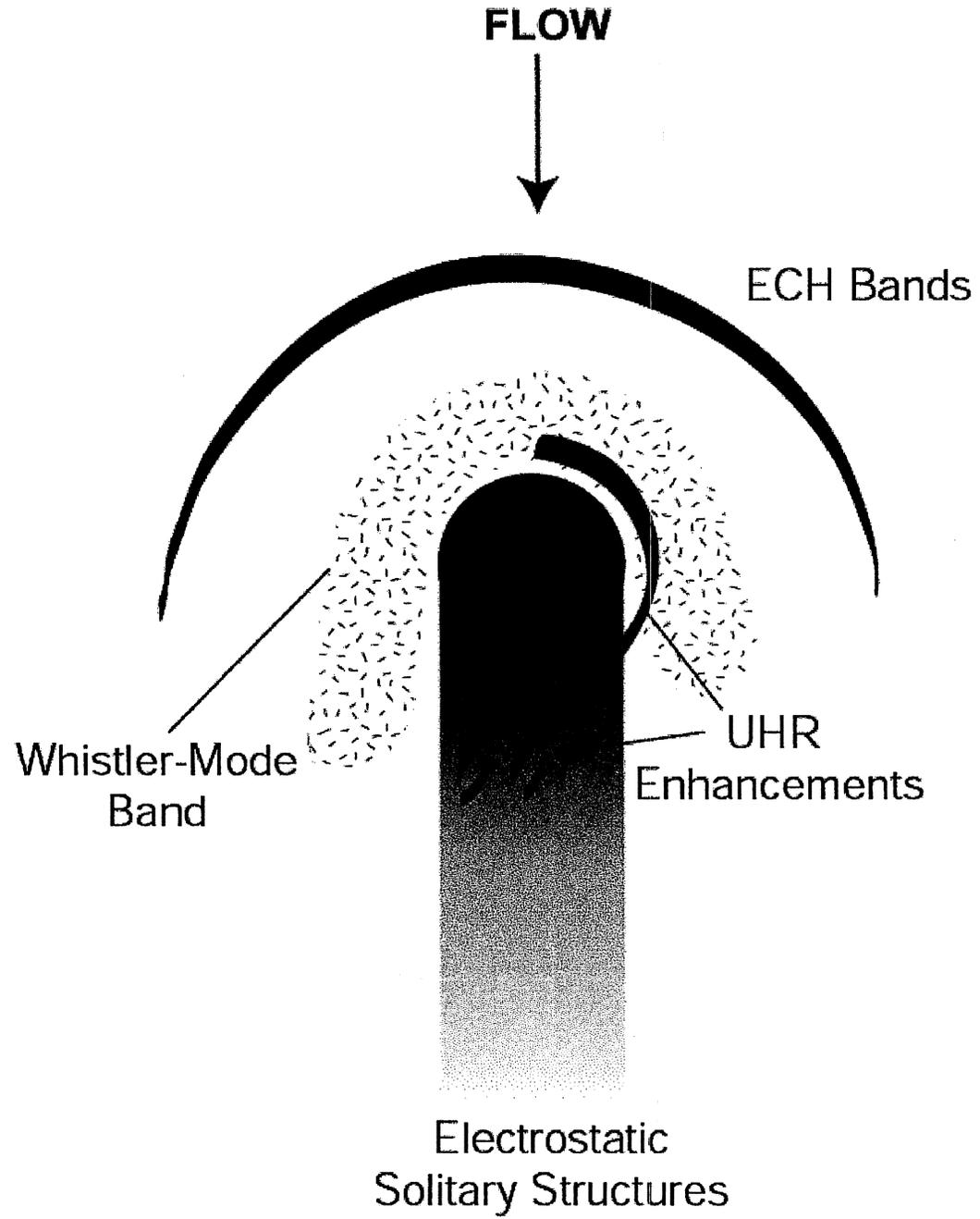


Galileo – Ganymede 1
27 June, Day 179, 1996

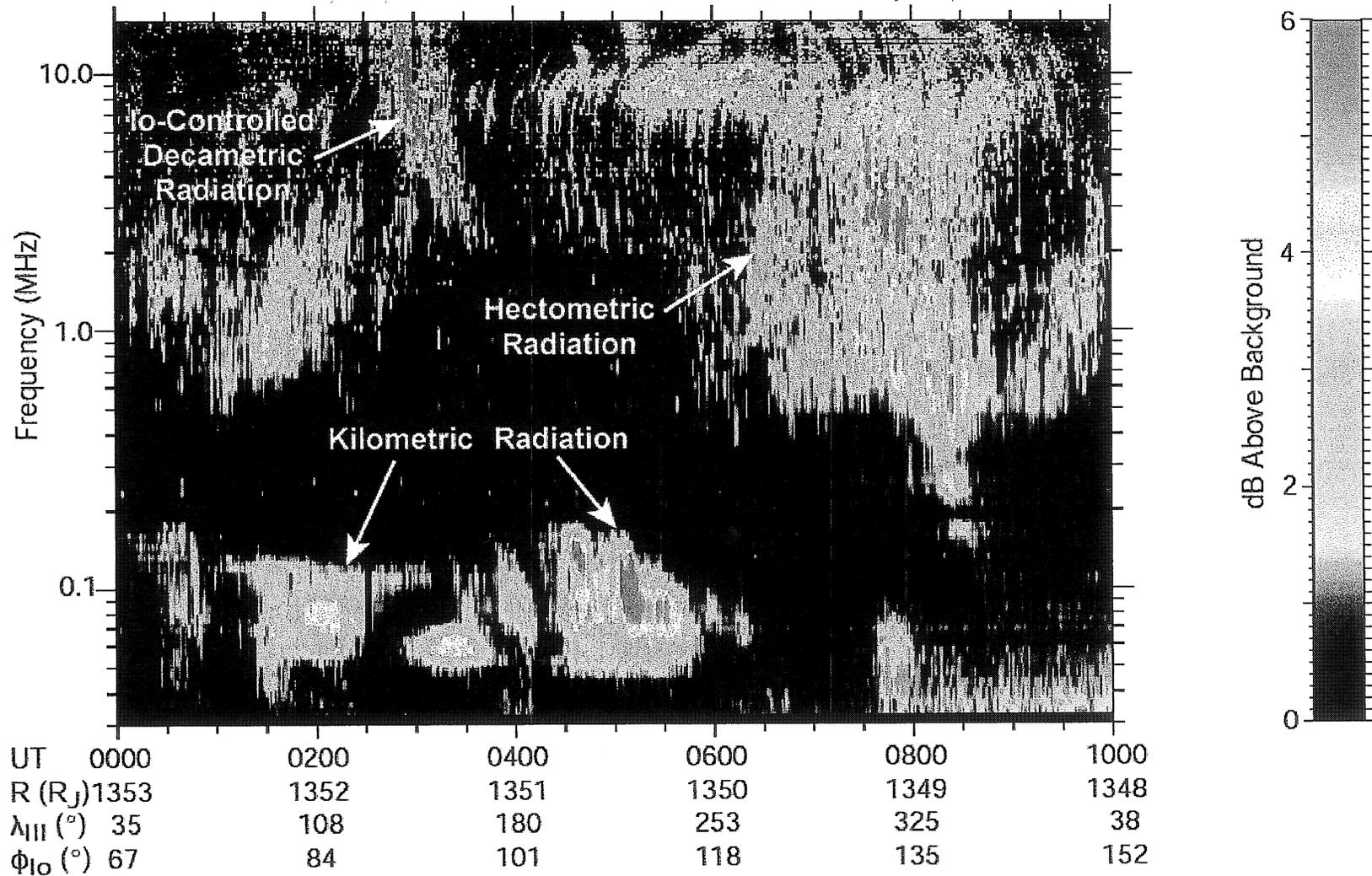


EUROPA 4 19 December, Day 354 1996

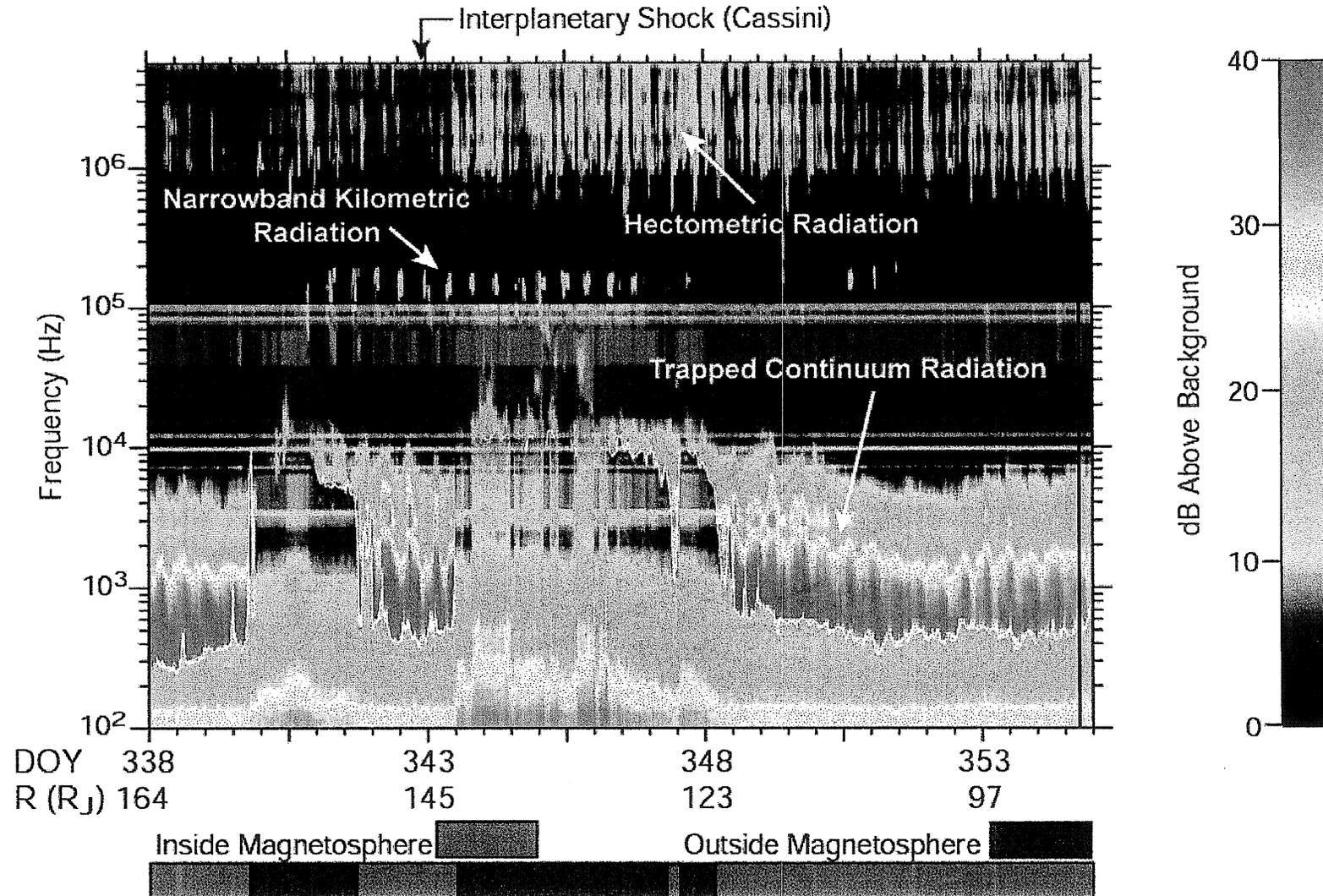


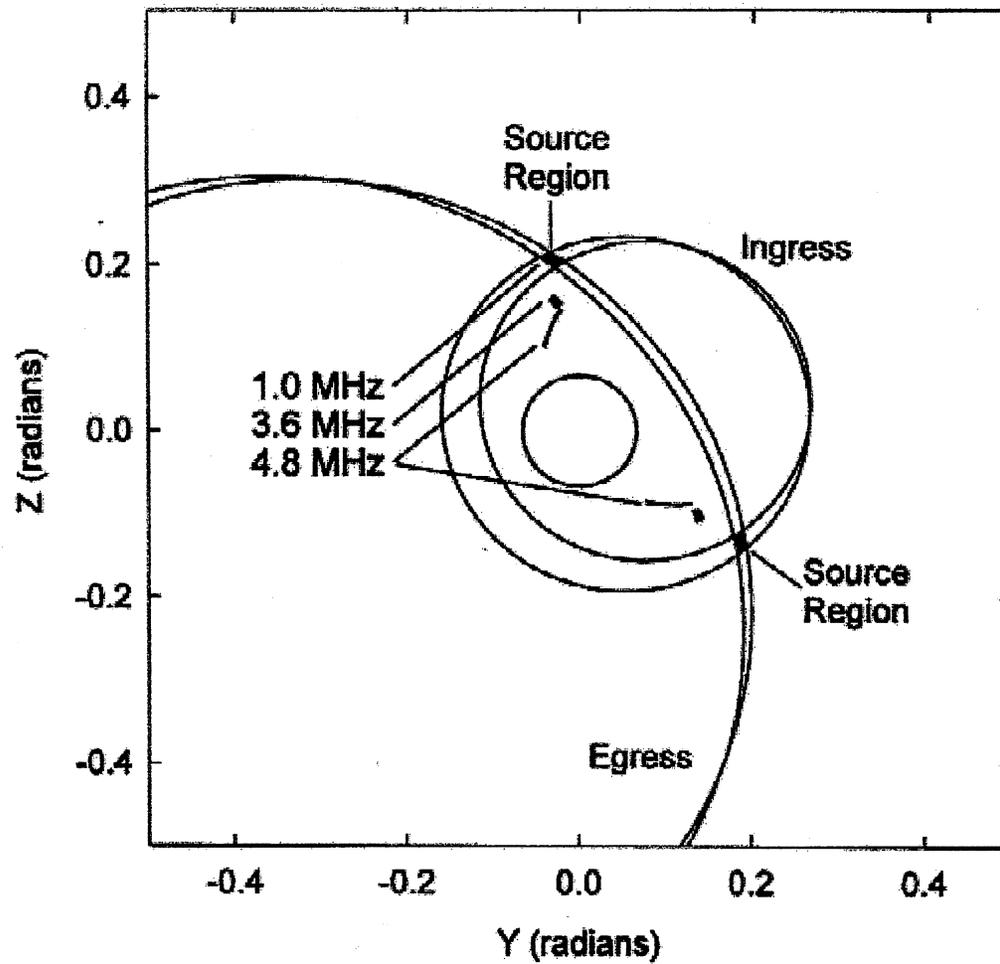


Cassini RPWS September 18, Day 262, 2000



Galileo, December 3 - 20, Days 338 - 355, 2000





Measurement Objectives

- Subsurface radar sounding
 - Frequency Range: ~ 1 to 10 MHz
 - Lower limit imposed by ionospheric density
 - Upper limit suggested by assumption of higher frequency radar (~50 MHz) and need for different antenna (low gain) for the longer wavelengths, hence, different techniques for removal of ground clutter
 - Radiated Power: few Watts or greater
 - Limited by impedance mismatch with plasma and upper limit to antenna voltage
 - To be investigated

Measurement Objectives, cont.

- Plasma Density
 - Ionospheric densities to $>20,000 \text{ cm}^{-3}$
 - In situ plasma densities as low as 0.01 cm^{-3}
- Radio and Plasma waves (Electric component)
 - Frequency range: $< 1 \text{ Hz}$ to 40 MHz
 - $15 \text{ nV/m} \cdot (\text{Hz})^{1/2}$ at 10 kHz , 100 dB dynamic range
 - 3 components
 - Polarization,
 - Direction of Arrival
- Plasma waves (Magnetic component)
 - Frequency range: $< 1 \text{ Hz}$ to 15 kHz
 - $50 \text{ pT}/(\text{Hz})^{1/2}$ at 100 Hz , 100 dB dynamic range
 - 3 components
 - Wave-normals
- DC Electric Field
 - Sensitivity: $<25 \text{ mV/m}$

How JIMO Extends Galileo Magnetospheric Science

- Low Gain Antenna mission (low data rates) forced lower resolutions in time, frequency, energy, composition
- Even multiple flybys of Galilean satellites (9 in the case of Europa) leaves considerable ambiguities in structure and dynamics of magnetospheric interaction; high inclination, spiraling orbit should resolve many of these
- 1970's technology and instrumentation simply isn't capable of making the next level of advances in measurements.

Accommodation Issues

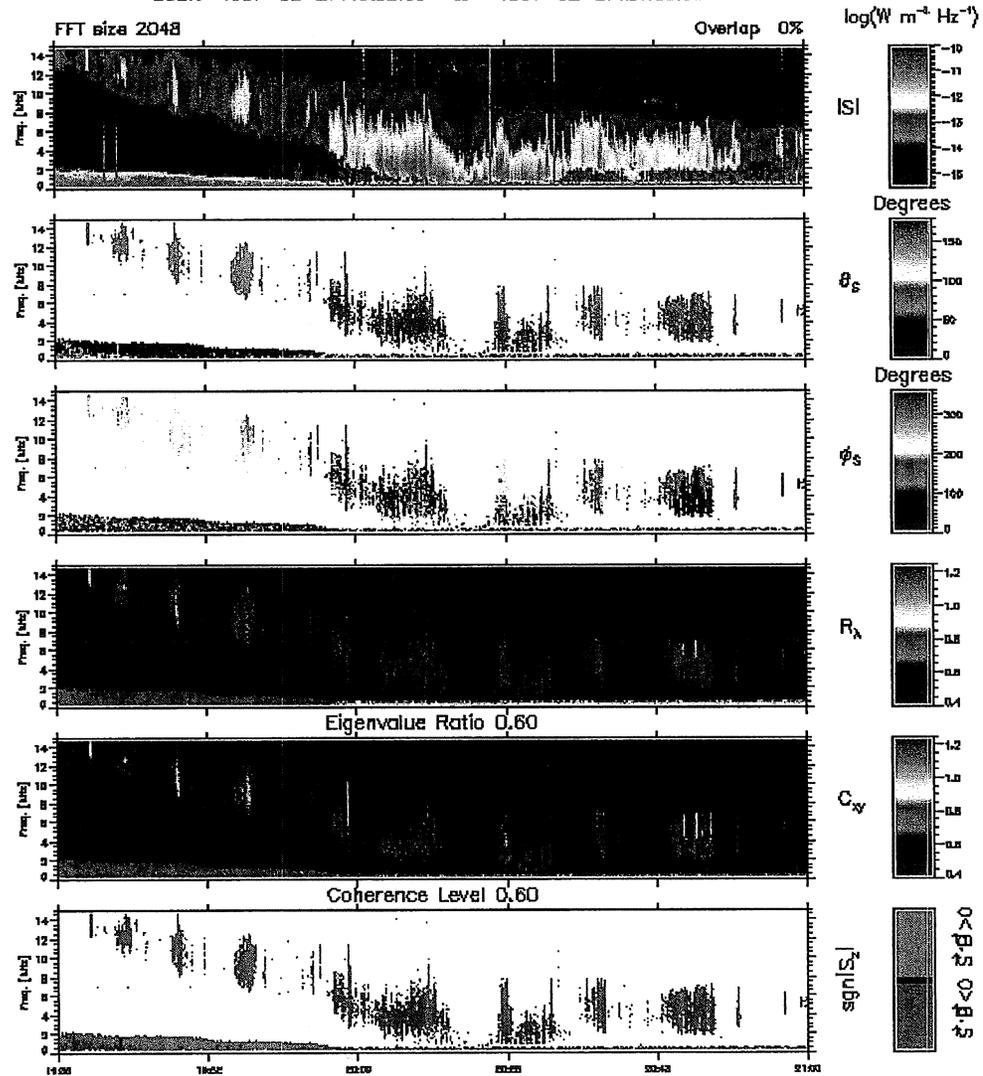
- Electromagnetic cleanliness challenges
 - High power reactor/systems
 - Ion thruster
- Multiple antennas/booms
 - LF Radar sounding antenna
 - 3-component electric field for direction-finding and polarization
 - 3-component wave magnetic field for wave-normal analysis

Backup Slides

W. S. Kurth

Polar PWI HR HFWR Poynting Flux Direction

SCET: 1987-02-27T19:35:00 to 1987-02-27T21:00:00



R_E	3.59	4.04	4.47	4.87	5.25	5.60
λ	25.68	34.48	41.53	47.36	52.28	56.48
MLT	14.93	14.96	14.96	14.94	14.91	14.85
L	4.48	6.01	6.04	10.67	14.08	18.40
Fce	22.04	17.49	14.20	11.34	8.89	7.67

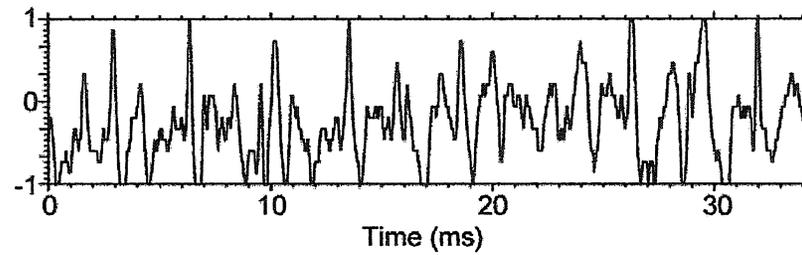
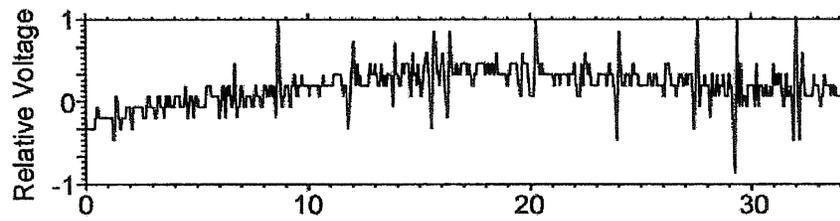
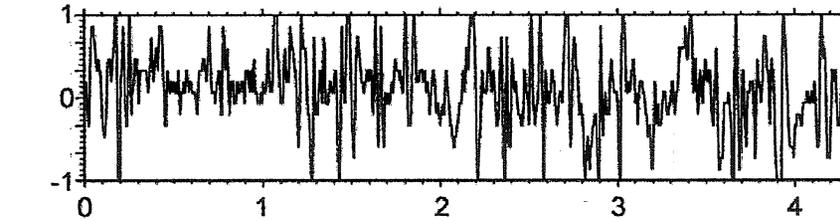
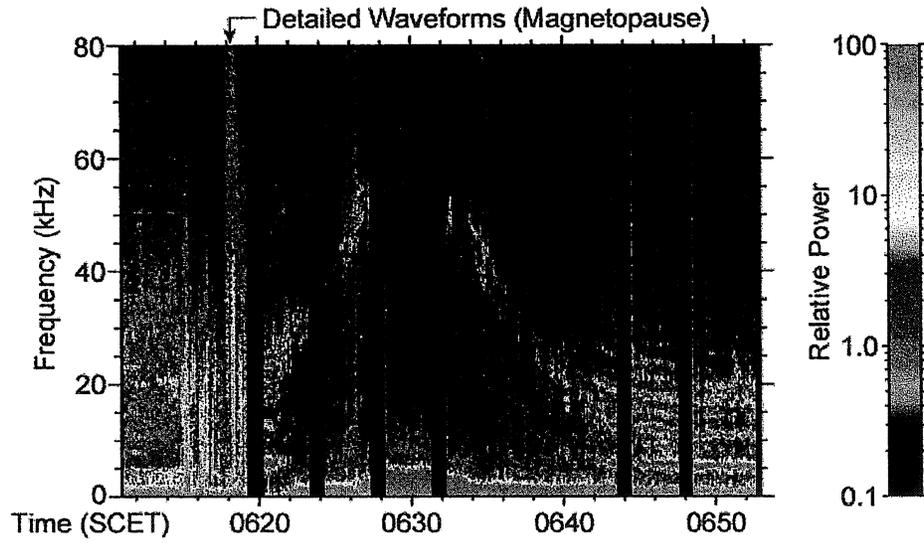
dt = 9.200 sec.

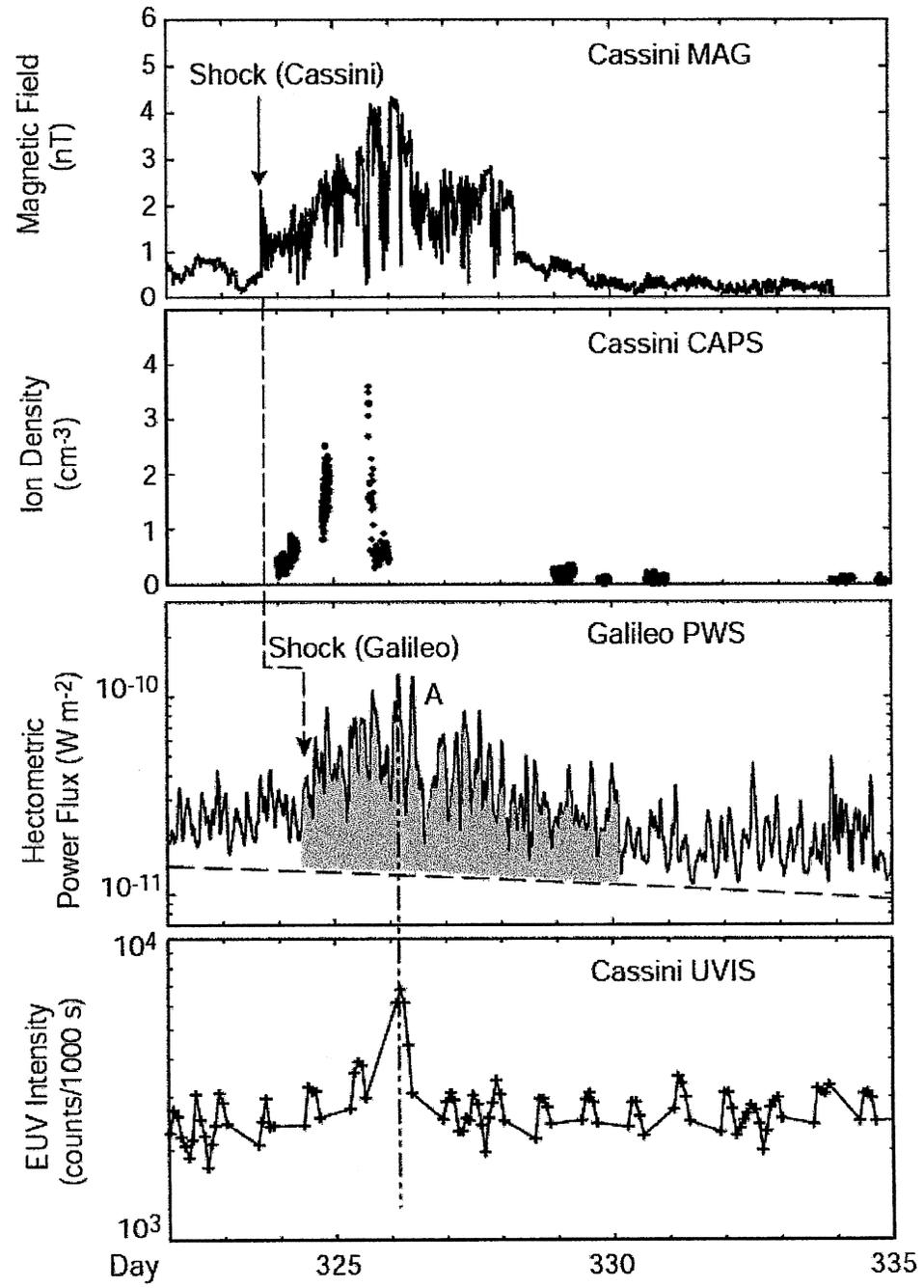
f0 = 0.16 Hz

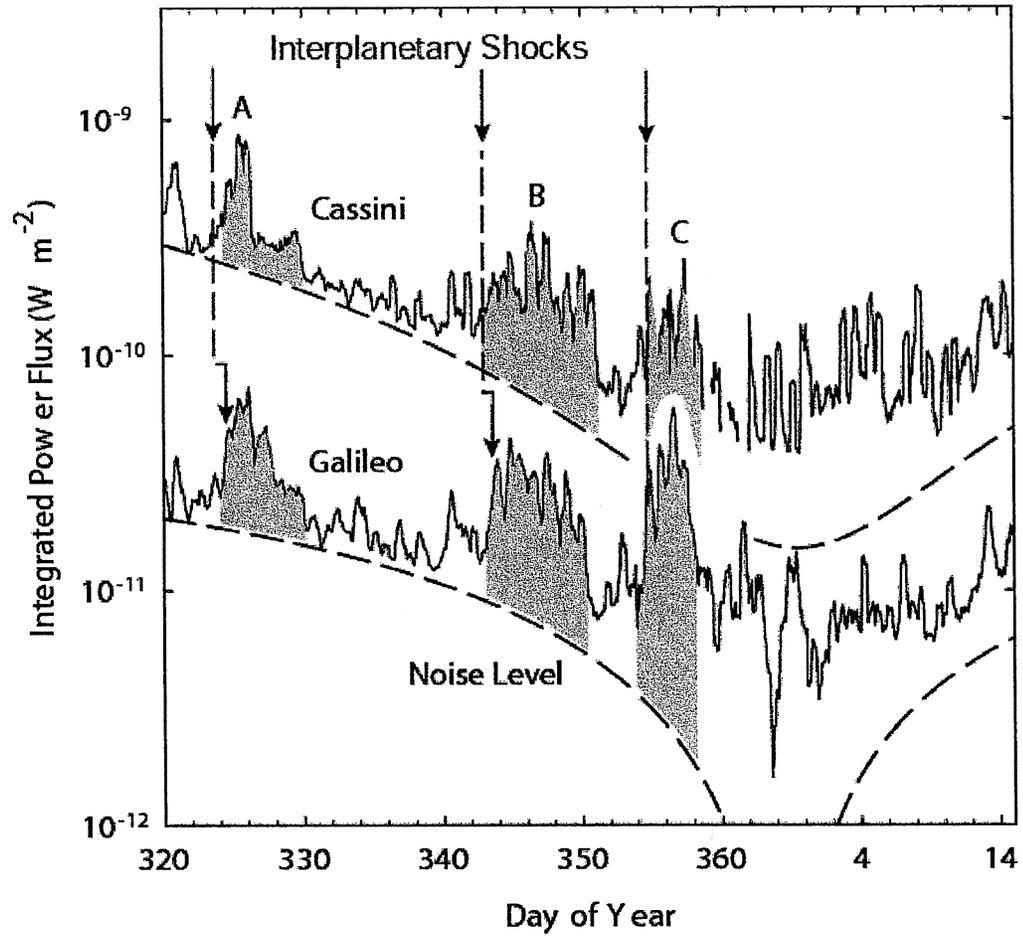
df = 139.51 Hz

Ulowa 991103

Galileo, Ganymede 1, June 27, Day 179, 1996







Sample Returned Power Calculation for MARSIS

